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ABSTRACT

Computer-assisted instruction supplements traditional methods in a non-calculus physics course offered at Seattle Pacific College. Thirty-five science majors enrolled in the first quarter and 32 continued in the second term. The hardware for the course consists of a PDP-11/20 computer and eight teletype terminals; additional peripheral equipment includes a card reader, a card punch, a line printer, and two ports for phone lines. Core size is 7K but four discs contain 2.9 million words. Batch and conversational modes are possible in the system and the BASIC-PLUS language is used. Four categories of CAI activities are noteworthy. First, eight canned programs--LUNA, VECTOR, SEESAW, CAN, INCLIN, NEWTON, CIRSAT, and HARMOT--are used to teach units on vectors, statics, freefall and projectile motion, mechanics, gravity, oscillations, and wave motions. Secondly, students write their own programs to solve problems. In addition, the computer is used to monitor tests, providing immediate feedback, allowing students to rework missed problems, reducing time pressures, and permitting limited self-pacing. Finally, computer graphics, utilizing a Tektronix 4010 graphic terminal, are being introduced into the course. (PB)

THE USE OF A PDP-11/20 COMPUTER IN A NON-CALCULUS GENERAL PHYSICS COURSE

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I would like to share my experience of using the computer in a non-calculus general physics class for science majors. I would like to first of all thank the National Science Foundation for providing me with an opportunity to participate in the Institute on Computer Use in Undergraduate Instruction at Illinois Institute of Technology last summer. In a sense, this year's class is a kind of testing ground for some of the ideas which germinated during the summer institute. In addition, there have been several new things developed during the course of the year. I would like to expand on some of these in this report.

I should also describe to you the computer configuration that we have at Seattle Pacific College. We have at the present time a time-sharing PDP 11/20 computer with eight teletype terminals. The peripheral equipment includes a card reader, a card punch, a line printer and two ports for telephone lines. There is also a portable terminal that can be checked out by faculty members for using the computer in the office or at home. The core size is only 7K for each user; but there are two small and two large disks which can contain up to a total of 2.9 million words. The computer is capable of handling both the batch and the conversational modes, the latter being the preferred one. The primary language used is BASIC-PLUS, which is essentially a sophisticated version of BASIC with many additional string capabilities. I should emphasize, however, that most of the things that I am going to talk about do not depend very much on the specific hardware and software. And if they do, modifications can easily be made to make them compatible with other computer configurations.

I will next describe the general class profile of the course that I am reporting here. The one-year introductory course in general physics has been attended by a variety of students who had some exposure to high school physics, although this is not a requirement of the course. Most of the students major in science subjects such as chemistry, pre-med, engineering, biology and nursing. There are some elementary and high school teachers. The 5-hour course started with 35 students in the fall quarter. In the beginning of the winter quarter (when this paper was written) there were 32 students. This reflects a retention rate of 91.5%, the highest ever in this course sequence. The male/female ratio, however, was up from 5/1 to 8/1 for these two quarters. It has been found helpful to group the students in the class into sections, each consisting of three to four people. Generally, resident and commuting students belong in different groups. Students in the same group get together frequently to discuss their common problems in homework assignments, including the use of the computer.

This leads me now to discuss the actual use of the computer in the class. For convenience, I will divide the computer-related activities into four categories. These are a) canned programs, b) problem solving using the computer, c) test monitor, and d) graphics. At this writing, only experience in the fall quarter will be reported.

I will now discuss the four types of activities in turn.

Canned Programs

In terms of both student and instructor use of the computer, this activity consumes the largest amount of time. Since most of the students had no previous programming experience, the canned programs were in fact their only means of gaining access to the computer in the earlier part of the course. The Dartmouth BASIC was introduced during the first week of class and the majority of the students quickly caught on and began to write their own programs. However, canned programs continued to be in use, since they provided simulations and illustrations to selected problems which complemented lectures well. Let me now briefly describe the canned programs I used during the fall quarter and the principles each tries to illustrate.

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LUNA--To generate interest with the computer and to familiarize students with the mechanics of signing on and off the system, I used a one-dimensional version of this time-honored problem of lunar landing simulation. Since most people here are probably familiar with this problem in one version or another, I will not elaborate on the program. It is an easy program to write and gives the students a lot of fun and experience of testing their intuition about the effects of various forces on motion. The only thing one has to watch out

for is that in many versions of the lunar landing simulation, the fact that the mass of the lunar module decreases after burning out some fuel has sometimes been neglected. This bothers some of the brighter students. I made this approximation in my canned program. A student later caught it, put in the proper corrections, and found that the approximation was pretty good in most cases. I put this program on the computer during the first week of class. Everybody in the class tried it and about half of them were able to land successfully (i.e., within five feet/sec.).

VECTOR--This program helps the students practice the algebraic method of vector additions and subtractions both in the rectangular and the polar coordinates. It handles things like transformation between the vectors in the two coordinate systems. Given the components, it computes the magnitude and angles, and vice versa. Since the vector concept was to be used throughout the course, it was important that the student understand it thoroughly and be able to manipulate vectors at ease.

SEESAW--We followed the sequence of subjects organized in the textbook Physics: Foundations and Frontiers by Gamow and Cleveland. So statics came before dynamics. In this program, the student can place weights one after another on a meter stick. The object is to balance the meter stick after a specified number of weights. It's a simple program to illustrate the conditions of equilibrium, and the concepts of force and torque. With the conversational mode, as adopted for all the canned programs, the student gained a sense of reward in playing the "game" if he succeeded in balancing it.

CAN--The problem of shooting a monkey on a tree is simulated with this program. A gun is aimed at a monkey initially sitting on a tree. At the instant a shot is fired, the monkey falls down from the tree. The bullet invariably hits the monkey as long as its initial speed is above the certain minimum. This simulation was "played" by the students along with the viewing of a series of stroboscopic pictures taken from an actual experiment (the monkey is replaced by a steel ball). In the computer simulation, the student was able to vary the initial speed of the bullet, the initial height of the monkey and the initial distance of the gun from the tree. He had the option of printing out a table of the positions and velocities of the bullet and the monkey at regular intervals, or a graph of the trajectories, or both. He could also choose to have none of these printed out, but only the height and the time at which the bullet hit the monkey. The program was written again in the form of a game, so that the student could first select a particular height, and try to set up the initial speed of the bullet in order to hit the monkey at the particular height. This program illustrates the free fall and the two-dimensional projectile motion at the same time.

INCLIN--The classical inclined-plane problem sooner or later encountered in mechanics has a surprisingly large number of variations if all the possible motions are taken into account. These depend on the initial velocity of the object on the incline, the angle of inclination and the coefficient of friction. The program first analyzes the different forces acting on the object given a set of initial condition. It then simulates the different situations which would arise from these conditions. The student was free to choose any or all of the parameters necessary in the problem and he was encouraged to "confirm" the computer's result with his own calculations.

NEWTON--The concept that a given force plus a given set of initial conditions determine completely the motion of a particle in classical mechanics is illustrated in this program. The program utilizes the method of 4th order Runge-Kutta to solve the differential equation embodied by Newton's second law of motion. The student was first asked to try out the program using a constant force and to discover that the results were the same as those produced by a simpler method. He was then encouraged to try a different form of the force such as Hooke's law, and to find out the resulting motion. Results were obtained either in tabular or graphic forms.

CIRSAT--After a discussion of the universal law of gravitation in class and the subsequent planetary and satellite motions, the student could try out this program. It describes the motion of a satellite in a circular earth orbit and relates the period, the speed and the height of the satellite above the earth. Several features of Kepler's laws of planetary motion, such as the dependence of the period on the height, were also clarified with the aid of the program.

HARMOT--Finally, by the end of the quarter we came to the chapters on oscillations and wave motions. By this time the students had a pretty good idea how forces were related to the motions (partly through the NEWTON program). He can now launch into a detailed study of the harmonic motion with and without damping forces. The program also had the option of putting in a driving force, from which the phenomenon of resonance follows. Most students did not get that far, however, since it was close to the end of the quarter.

During the middle of the quarter, we also had the students try out the One Week Sample Course on Introductory Computer-Based Mechanics developed by the Commission on College Physics. The students had little difficulty in following the material and were generally open and receptive to the approach.

Programs Written by Students

The second area of computer use in the class has to do with programs written or modified by the students. This started as soon as they had an hour of instruction in BASIC during the first week. Naturally some students were more anxious to do this than others. However during the course of the quarter, all of the students in the class had some programming experience. They did this by solving problems in homework assignments or as extra-credit problems to be turned in at the end of the quarter. The students generally found that the availability of the computer was an asset and that the process of breaking a problem down to smaller components helped them to face the task of problem solving. I will only mention a few of the programs that the students have written:

BIRD--The problem of a bird flying back and forth between two trains approaching each other has a well known theoretical answer; namely, assuming the bird has no size and that no time is lost in turning around, the bird can take an infinite number of trips. A program was written by a student to take into account the finite size of the bird and it showed that for reasonable values of the bird's size and reasonable speeds, only a few trips in fact were possible before everything crashed. This is a simple program. Nevertheless, it shows the student's interest in pursuing a problem using the computer.

LEM--A more ambitious student extended the LUNA program discussed earlier to the two-dimensional case and did this for his extra-credit problem. He was successful in completing the problem. However, he did express frustrations on the number of mistakes he made before getting the program to work. This was undoubtedly due to the complexity of the problem for a student in the beginning physics class. Even though I was delighted and was rather proud of his achievement, probably the problem was at the limit that the student could handle. I have a hunch that a simpler problem probably would illustrate just as much physics, although not as much computing. Since the purpose of computing is to provide insight and not just more numbers, in the future large, elaborate programs probably should not be encouraged.

RENDEZ--A couple of students collaborated on this project and wrote a program for rendezvous with an orbiting spaceship. A minimum-energy orbit was chosen for the rocket which is to meet the spaceship already in the circular orbit. They seemed to enjoy the experience of working out the problem and putting the program to work.

Obviously I have chosen to discuss the three examples representing the simple, the tedious and the "medium" programs which the students have tackled. The level of involvement varied widely within the class. However, as stated earlier all students in the class had programming experience by the end of the quarter. Part of this experience was gained in the weekly assignment. Usually a number of questions were assigned to the students. They were to be solved analytically with a pencil and a piece of paper. However, each student in each of the study groups was supposed to do one of the assigned problems using the computer. Sometimes this could be just a simple arithmetic expression; sometimes it could involve quite a few more steps as in the case of a pendulum swing with large amplitudes. Students liked the variety of approaches and also the opportunity for discussing problems among themselves. The only complaints that I received had nothing to do with the approach or philosophy, but rather hinged on the administration of the computer, which was handled by a separate office. These complaints, ranging from frequent shutdowns of the computer without adequate advance notice, to inadvertent loss of saved programs on disk by system operators, could certainly be avoided as the computer personnel gained experience in the management of the hardware.

Test Monitoring

The third type of computer use in the class that I would like to report has to do with test monitoring. This was a relatively new idea and had been tried out only during the second half of the first quarter. A series of test monitoring programs had been written which allowed students to take tests on the teletype terminals and be graded immediately. The advantages of this are several; (a) the student knows right away how he does on the test; (b) he has a chance of redoing problems with proportionately discounted (but not zero) points; (c) he has less time pressure when he takes the test on the teletype terminal, and it does not take away class time; and (d) he can take the test when he feels ready to do so (within limits, of course). So far I have used this method only for weekly quizzes, not on the mid-term and the final examination. The software needed for test

monitoring consists of several programs. These will be briefly described below. I would be glad to talk to anybody who would like more details on these programs.

The first program creates a file of the names of the people in the class. A second program creates a file of the test, and a third one, a file of the corresponding answers. The main program which monitors the test is stored on a disk in compiled form. It performs all of the following functions. First, it creates a master file which serves as a directory to the different files to be used, including the roster, the test, the answer and the result files. When the student is ready to take the test, the program checks for his name in the class roster allowing only those in the roster to take the test, and preventing anyone who has taken the test earlier from taking it again. It then prints out the test questions, one at a time, and the student answers by typing on the teletype terminal. The computer checks the student's answer against that on the answer file; if the answer is correct, he will be told so and given the full credit on that question; if the answer is not correct, he will be given a second chance to try the same question and be given only a fraction of the full credit if his second answer is correct. After all the questions have been answered, the program adds up the total score that the student gets for that test and prints it out for the student. It also records the student's grade on a result file; at the same time it puts a mark on the roster file to note the fact that the student has already taken the test. Finally, the insturctor can have the result file printed out after everybody in the class has taken the exam. A separate program can be used to calculate the average and standard deviation of the curve for the test results, and to plot out the histogram. The student turns in his copy of the test from the teletype immediately after he is done, so that in case of computer error the instructor can always check against the copy.

Of course one problem of this approach in giving the test is security. The programs have been written with this taken into consideration. For instance, students cannot gain access to any of the files except through the test monitoring program. And each person can use the program only once for each test. However, this certainly does not prevent the students from discussing the test among themselves. If the students know that giving away information may hurt their own points, they are generally not inclined to do such things.

Computer Graphics

Another area of computer use which I have just started is computer graphics. In principle, if one has graphic terminals and the appropriate software, this application is no more difficult than with the teletype terminal. In practice, however, the variety of available graphic terminals plus the lack of a standard software package, make it necessary for everybody to do his own graphics. I had a demonstration model of Tektronix 4010 in my office over the Christmas recess and by the beginning of the new quarter I had enough software developed to make it usable. The advantages of the graphic terminal over the teletype terminal are manifold. It is silent. It is fast. It can draw pictures. And the display area does not move with each carriage return and line feed. To my mind there is little doubt that the graphic way is the way to go in the future. We are hoping to get some of these terminals soon. But until then, we are stuck with what we have.